

From the Editors' Desk:

FALL 2016

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Over the past year, change has been the only constant in the North American railway industry. After setting an all-time record for freight ton-miles in 2014, US Class 1 freight traffic declined in 2015 and early results from 2016 suggest this downward trend is continuing. Traditional sources of bulk freight traffic such as coal have declined substantially on many rail corridors due to changing energy markets. Recent gains in freight rail transportation related to energy production have been slowed due to slumping oil prices. Lower-cost diesel fuel has also made trucking more competitive for many types of carload and intermodal shipments. International container traffic is just now starting to respond to the opening of the expanded Panama Canal this past June. On the passenger side, lower gas prices have slowed ridership growth on intercity, commuter and rail systems. However, public interest in new and expanded passenger rail service remains strong in many communities, with several lines under study, in construction or newly opened. Progress continues to be made on high-speed rail projects in California and Texas.

These short-term traffic trends provide RAS members with a continually evolving set of railway planning, operations and management challenges. Locomotives and railcars are placed in storage while crews are reassigned. As traditional bulk traffic sources decline, freight railroads are “re-writing the playbook” with an emphasis on intermodal and carload traffic. Long-standing approaches are being questioned. There is a renewed focus on the reliability and resiliency of operations. Careful planning and coordination is undertaken to accommodate higher-frequency and higher-speed passenger service through congested urban terminals.

In optimizing railroads for current conditions and short-term trends, RAS members are challenged to not lose sight of the larger, longer-term trends that will drive the future of freight and passenger rail operations. In his famed text “*Economic Theory of Railway Location*”, Arthur M. Wellington advised against solutions that presented short-term benefits but resulted in “permanent handicaps” that would threaten the long-term viability of the railway enterprise. Today’s optimal railway operations and management decisions can limit the solution space of the future.

What might these future railway OR decisions entail? A recent US Department of Transportation report, “Beyond Traffic 2045: Trends and Choices” identifies multiple challenges that may impact the future performance of the multimodal transportation network. In the face of increasing population, evolving demographics, changing travel patterns, shifting commodity flows, aging infrastructure, climate change and availability of funds, rail must continually adapt through research, innovation and data-driven solutions. Specific challenges facing freight and passenger rail network over the next 30 years include:

- Increasing demand for fast and reliable passenger rail service in growing megaregions
- Ridership growth and challenges of meeting the cost of national passenger rail service
- Increasing freight rail demand magnifies bottlenecks and passenger train conflicts
- Continued emphasis on sustained improvements in rail safety

The decisions of RAS members will directly influence how both passenger and freight rail systems can meet these challenges by adapting to new operational requirements, preserving service, handling expanding transport demand and improving safety over the long term.

Keeping this in mind, we challenge you to think of and discuss both the short and long term during the 12 RAS sessions at the annual INFORMS conference in Nashville. These sessions and other RAS conference activities have become possible because of membership fees and generous contributions from our sponsors. We thank you, our members and sponsors, for your support.

See you in Nashville!

Tyler and Xuesong

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➤ RAS Sponsors

RAS is proud to serve its members via activities that help advance the application of operations research and analytics to railroad problems. Our events are organized by volunteers with a great sense of commitment and dedication, and we are very thankful for their time. These activities also involve a significant amount of money, so we rely on their financial support. This year we have raised over \$10,000 with the support of these sponsors, and we thank them for their continued time and generosity.



BNSF Railway is one of North America's leading freight transportation companies, with a rail network of 32,500 route miles in 28 states and two Canadian provinces. BNSF is one of the top transporters of the products and materials that help feed, clothe, supply and power communities throughout America and the world. BNSF moves these goods more safely and efficiently, on significantly less fuel and with fewer emissions than the all-highway alternative.

CSX Corporation, together with its subsidiaries based in Jacksonville, Fla., is one of the nation's leading transportation suppliers. The company's rail and intermodal businesses provide rail-based transportation services including traditional rail service and the transport of intermodal containers and trailers. Overall, the CSX Transportation network encompasses about 21,000 route miles of track in 23 states, the District of Columbia and the Canadian provinces of Ontario and Quebec. The CSX transportation network serves some of the largest population centers in the nation. Nearly two-thirds of Americans live within CSX's service territory.

GE Transportation is a global digital industrial leader and supplier to the rail, mining, marine, stationary power and drilling industries. GE Transportation's solutions help customers deliver goods and services with greater speed and greater savings using advanced manufacturing techniques, industry expertise and connected machines. Established more than a century ago, GE Transportation is a division of General Electric Company that began as a pioneer in passenger and freight locomotives. GE Transportation now provides railroads with data-driven insights to address key customer metrics like velocity, fuel, reliability, productivity and dwell. Headquartered in Chicago, GE Transportation has over 65 service sites worldwide. Visit <http://www.getransportation.com/> for more information.

Norfolk Southern Corporation is one of the nation's premier transportation companies. Its Norfolk Southern Railway Company subsidiary operates approximately 20,000 route miles in 22 states and the District of Columbia, serves every major container port in the eastern United States, and provides efficient connections to other rail carriers. Norfolk Southern operates the most extensive intermodal network in the eastern United States and is a major transporter of coal, automotive, and industrial products.

Oliver Wyman, the fourth largest strategic consulting firm, is the premier consultancy for railways in operations planning and improvement, regulatory matters, process improvements and strategic guidance. In addition to consulting, their award winning MultiRail planning suite software is in use by many major railways in the United States, Canada, Mexico, Europe, Asia and Africa to provide business management for the entire operating plan process.

Optym is a leading provider of advanced planning, scheduling and business intelligence solutions for the global transportation and logistics industry. The company's clients include railroads, mining companies, airlines, trucking companies and major retailers. Based in Gainesville, Florida, Optym develops its optimization, simulation and data analytics software using an innovative blend of operations research, computer science and vast industry knowledge. Optym was founded in 2000 and consists of over 130 highly skilled professionals with offices in four countries. Visit www.optym.com for more information.



2016 Distinguished Member Award: Dr. Dharma Acharya



RAS is able to serve our profession through the contributions of volunteers. Although help from everyone is appreciated, some volunteers' contributions have a far reaching impact. Their work has given RAS a new direction and continues to inspire others to follow their footsteps. The RAS Distinguished Member Award recognizes such individuals. The award committee consists of the current officers, past award winners and past RAS Chairs/Presidents.

Dr. Dharma Acharya is the recipient of the RAS Distinguished Member Award for 2016. Dr. Acharya retired in 2015 from his role as the AVP of Operations Research at CSX Transportation after more than 20 years of distinguished service. Since June 2016, he has served as Sr. Staff Operations Research Leader at GE Transportation.

Dr. Acharya received his Ph.D. in Transportation Systems from Massachusetts Institute of Technology in 1990.

Throughout his professional career, he has a continuing interest in applications of new and emerging technologies that benefit the railroad and freight transportation industry. His work has also led to numerous awards in recognition of his significant contributions to operations research applications in railway engineering, including the highly competitive INFORMS 2009 Franz Edelman Finalist Award, the 2015 INFORMS Daniel H. Wagner Finalist Prize, and the 2001 CSX President's Award of Excellence. Dr. Acharya's outstanding participation and leadership with RAS has spanned over two decades. Since 1997, he has been an active member and enthusiastic supporter. He has served on multiple important RAS positions, including Cluster Chair, Chair, Vice Chair, and Treasurer of RAS (then called the Rail Applications Special Interest Group). In addition, he served as session chair for many RAS annual meetings, presented numerous papers, and actively supported many RAS activities including the RAS paper contest, the RAS student paper contest, and RAS problem-solving competitions.

Dr. Acharya's passion for the field is also evident in his role as the head of the department of Operations Research at CSX. His dedication to his career and his collaboration with the best in the field has brought several pioneering changes in the application of OR at CSX. Dr. Acharya has been instrumental in taking OR applications beyond Service Design at CSX. Dr. Acharya has proved himself to be an outstanding practitioner of Operations Research in rail application, contributing to algorithms, analysis, and the adaptation in dozens of applications. His intelligence, dedication, and attention to detail is exemplified through the innovative perspective he consistently brings to each project with which he is involved.

In summary, Dr. Acharya has made profound and far-reaching impacts through his many research efforts and public services. His vision and efforts on promoting operations research in the railroad industry is unparalleled. Even after retiring from CSX, he continues to contribute to the railroad industry, as well as RAS, at a steady pace. Congratulations to Dr. Acharya for winning this year's INFORMS Distinguished RAS Member Award.

RAS Problem Repository

The RAS Problem Repository was created in 2011 to facilitate a platform on which:

1. Real-life railroad application problems are presented along with dataset(s) and solutions publicly available for anyone to research, develop and test solution approaches.
2. Researchers may showcase their results, engage in questions, answers and discussions, and measure the performance of different solution approaches.

You can find the problem description and data files on our website: <http://informs.org/Community/RAS/Problem-Repository>.

We have added the initial version of "Integrated Train Timetabling and Maintenance Scheduling" to the repository. We encourage researchers to submit different problems to add to the repository. Please contact RAS officers to upload your problem.

Have News to Share?

Published a paper? Published a book? Hiring for full timers or interns? If you have news that you would like to share with RAS members, please let us know. We can help spread the word.

Look forward to seeing you in Nashville!

➤ Updates from RAS Officers

Xuesong Zhou, Arizona State University; xzhou74@asu.edu

Vice Chair: April Kuo, BNSF Railway; april.kuo@bnsf.com

Secretary: Shantih Spanton, CSX Transportation; shantih_spanton@csx.com

Treasurer: Gunnar Feldmann, Norfolk Southern; gunnar.feldmann@nscorp.com

Public Relations Officer: Tyler Dick, University of Illinois at Urbana-Champaign; ctick@illinois.edu

RAS Membership

RAS has a total of 101 members, out of which 86 are regular members and 15 are students. Compared to 2015, this is a decline of 13 members with losses evenly divided between regular and student members. We strongly encourage students (for a nominal fee of \$5 for INFORMS members and \$10 for non-INFORMS members), academicians and business practitioners (for \$15 for INFORMS members and \$25 for non-INFORMS members) to become RAS members to enjoy and benefit from many perks of being a member. These include the invitation to the RAS reception at the annual meeting, opportunity to meet with industry leaders and like-minded professionals, and notifications for the job/internship openings.

We are soliciting ideas to increase the number of student members. Please provide your thoughts during the RAS business meeting in Nashville!

LinkedIn and Email List

RAS has a LinkedIn group (visit <http://www.linkedin.com/groups?gid=2399643>) or simply search the Rail Applications Section of INFORMS). LinkedIn provides us a forum in which people can post and discuss topics. It is also used as part of communication during our RAS competitions. During the past four years, the number of members in our group has increased significantly to over 500. If you are not already a member, please join the group to connect with the other members from academia, railroads and consulting.

We also have a mailing list of all past and present RAS members. You can post job opportunities or reach out to other members for a specific question or discussion item.

➤ In Memoriam: Leo G. Kroon (1958-2016)

On September 14 2016, Leo G. Kroon unexpectedly passed away. Professor Kroon worked as a Professor of Quantitative Logistics at the Rotterdam School of Management (RSM), Erasmus University, and as a Logistics Consultant at Netherlands Railways (NS). He received his Master's in mathematics cum laude from the Free University in Amsterdam, and obtained his PhD in 1990 with Prof. Jo van Nunen at the Erasmus University.

Professor Kroon was foremost interested in railways, and worked since 1996 part-time at NS. Leo (co-)authored over 100 papers on mathematical optimization models for planning and real-time optimization. Furthermore, Leo has been the promoter of over a dozen PhD students, of which 10 worked on railway related topics. He twice won the PhD Supervisor Award of the national transport research institute TRAIL. Furthermore, two of Leo's PhD students won the RAS student paper competition.

Prof Kroon had a leading role in many international collaborations: he was the project leader for RSM for the EU-funded projects in railways AMORE, ARRIVAL, and ONTIME. He found great joy in organizing the international 2015 CASPT conference in Rotterdam with a team of his (PhD) students, colleagues, and his dearly beloved wife, Cisca. He was also Associate Editor of the journal Transportation Science.

Leo had a great ability to present even the most complex problems very clearly. The work of him, his colleagues, and PhD students often led to successful implementations in practice at Netherlands Railways in the areas of timetabling, rolling stock scheduling and crew scheduling. Leo and his team received many acknowledgements for their work, including the 2008 INFORMS Franz Edelman Award presented to the NS for model-based contributions to the 2007 NS timetable; the 2008 ERIM Impact Award and best paper award at the 2011 World Congress on Railway Research (theme "Even more trains, even more on time"); and 2013 Strategic University Relationship (SUR) collaboration with IBM.

Leo will be remembered as a brilliant and erudite researcher who was committed to his students, PhD candidates, and colleagues he worked with. He was honest, humble, and gifted with a subtle sense of humor. He leaves a big void in our community, but will live on in our minds and in his students' future work in optimization for railways.

-contributed by Evelien van der Hurk, PhD student of Leo, Assistant Professor at the Technical University of Denmark

RAS Sessions at the 2016 INFORMS Annual Meeting

Cluster Chair: **Mike Prince, BNSF Railway**; michael.prince@bnsf.edu

The 2016 INFORMS Annual Meeting in Nashville features 12 RAS sessions scheduled over four days. On Sunday we kick off with the RAS Student Paper Award, followed by two general sessions on scheduling and fleet size modeling and concluding with the RAS Problem Solving Competition. The Monday morning sessions cover intermodal operations and various techniques to manage network capacity. The RAS session continues on Monday afternoon with a session on safety research followed by a set of presentations on new approaches to blocking and trip planning. After a break on Tuesday, the RAS presentations resume on Wednesday morning with academic research on shared-use rail corridors, followed by a session on track maintenance analytics. The RAS program concludes on Wednesday afternoon with two sessions, one on yard and terminal operations, and a second on scheduling passenger-oriented networks.



RAS sessions are in Track 61 and will take place at the Omni, Room Cumberland 3 (with exception of Tuesday Roundtable)

Sunday, November 13

SA61: Railway Applications Section (RAS) Student Paper Award

Chair: **Steven Harrod, Technical University Denmark**

08:00 –
09:30

First Place: Rolling Stock Rescheduling in Passenger Railways Using Dead-Heading Trips and Adjusted Passenger Demand

Joris Wagenaar, Erasmus University (Coauthor: Leo Kroon)

Second Place: A Polynomial Function of Primary Delays and Cumulative Delays on Railway Lines

Fabrizio Cerreto (Coauthors: Otto Anker Nielsen, Steven Harrod)

Third Place: Balancing Performance of Timetable and Expected Schedule Robustness: Improved Space-Time Path Searching

Chao Lu, Beijing Jiaotong University

SB61: Advances in Railway Research

Chair: **Shantih Spanton, CSX**

11:00 –
12:30

1. CSX Line-of-Road Simulation (Yu Wang, CSX)
2. Crew Caller Districting with Consideration of Workload Balance and Geographic Compactness (Siyang Xie, U. of Illinois)
3. Scheduling Preventive Grinding for Railway Maintenance (Masoumeh Taslimi, U. of Illinois at Urbana-Champaign)
4. Scheduling Training Activities for Engineers and Conductors (Grigory Pastukhov, CSX)

SC61: Fleet Sizing Models

Chair: **Dharma Acharya, GE Transportation & Michael Gorman, University of Dayton**

13:30 –
15:00

1. Fleet Sizing Model Overview (Michael Gorman, University of Dayton)
2. Fleet Sizing Model: Freight Railroad Perspective (Clark Cheng, Norfolk Southern)
3. Intermodal Equipment Fleet Sizing (Bruce Patty, Veritec Solutions)
4. Fleet Sizing Model: Railroad and Shipper Perspective (Dharma Acharya, GE Transportation)

SD27: Railway Applications Section (RAS) Problem Solving Competition

Chair: **Lingyun Meng, Beijing Jiaotong University**

16:30 –
18:00

1. **Team 2.7.2:** François Galea, Sergiu Carpov, Loïc Cudennec, CEA, France
2. **Team NKCU:** I-Lin Wang, Fu-Yuan Cheng, Sih-Han Fang, National Cheng Kung University, Taiwan
3. **Team Railsmart:** Bisheng He, Yadong Liu, Yongxiang Zhang, Southwest Jiaotong University, China

Monday, November 14

08:00 –
09:30

MA61: Intermodal Transportation Chair: **Mike Prince**, BNSF Railway

1. Intermodal Empty Railcar Distribution Optimization (Shantih Spanton, CSX)
2. Intermodal Hub Simulation (Mike Prince, BNSF Railway)
3. Utilizing Rail Information in Intermodal Operations (Georgi Tasev, Schneider)

MB61: Practical Steps Towards Shipment & Network Capacity Management Chair: **Carl Van Dyke**, TransNetOpt

11:00 –
12:30

1. Managing Train Scheduling to Optimize Network Capacity (Dharma Acharya, GE Transportation)
2. Managing Intermodal Capacity through Differentiated Service Products and Load Acceptance (Carl Van Dyke, TransNetOpt)
3. Unit Train Management System (Hakan Golbasi, CSX)
4. Connected Driver Advisory System: Cost Efficient Rail Traffic Management Improvement (Per Leander, Transrail Sweden)

MC61: Rail Safety and Risk Chair: **Xiang Liu**, Rutgers, The State University of New Jersey

13:30 –
15:00

1. Analysis of Rail Accident Reports Using Probabilistic Topic Models and K-Means Clustering (Trefor Williams, Rutgers)
2. Statistical Modeling of Freight Train Accident Estimation (Zhao Wang, University of Illinois at Urbana-Champaign)
3. Simulation-based Risk Analysis Model for Optimizing Rail Flaw Inspection Frequency (Xiang Liu, Rutgers)

MD61: Advances in Blocking and Trip Planning Chair: **Shrikant Jarugumilli**, BNSF Railway

16:30 –
18:00

1. Arc Costing Approaches for Railroad Algorithmic Blocking (Erick Wikum, TCS)
2. Next Generation Blocking and Trip Planning Systems (Carl Van Dyke, TransNetOpt)
3. Modernizing Blocking and Trip Planning (Pooja Dewan, BNSF Railway)

Tuesday, November 15

08:00 –
09:30

RAS Roundtable 1: How to Leverage RAS to Better Serve the Rail Industry (*Room: Broadway H*) Chair: **Bob Gutman**, CSX Transportation & **Dharma Acharya**, GE Transportation

In this roundtable session, we will discuss ideas on how we could use the RAS Forum to help rail industry in leveraging the advanced analytics and operations research techniques.

11:00 –
12:30

RAS Roundtable 2: Future of Rail Network Optimization (*Room: Broadway H*) Chair: **Steven Harrod**, Technical University of Denmark & **Xuesong Zhou**, Arizona State University

In this roundtable session, we will discuss application of innovative technologies to automate the rail operations. The outcome of this session will be a list of areas where railroads could potentially apply new automation technologies to improve the efficiency of rail operations.



Wednesday, November 16

WA61: Shared-use Rail Corridor Operation and Planning

Co-Chairs: **Bo Zou**, University of Illinois at Chicago

08:00 –
09:30

1. Capacity Screening Tool for Mixed Operations (Mei-Cheng Shih, University of Illinois at Urbana-Champaign)
2. Schedule Flexibility and Shared Corridor Capacity (Darkhan Mussanov, University of Illinois at Urbana-Champaign)
3. Siding Length, Train Length and Traffic Capacity of Single-Track Lines (Bradford Kippen, U. of Illinois at Urbana-Champ.)
4. Capacity Allocation in Vertically Integrated Rail Systems: A Bargaining Approach (Bo Zou, U. of Illinois at Chicago)

WB61: Railway Analytics

Chair: **Qing He**, SUNY Buffalo

11:00 –
12:30

1. Estimating the Probability and Impact of Track Defects on Rail Maintenance Planning (Alexander Lovett, U. of Illinois U-C)
2. Predictive Switch Health (Casey Jen, CSX)
3. Data-driven Optimization of Track Inspection and Maintenance Using Markov Decision Process (Qing He, SUNY Buffalo)

WC61: Yard and Terminal Operations

Chair: **Tyler Dick**, University of Illinois at Urbana-Champaign

12:45 –
14:15

1. Switch-It: A New Yard Modeling Tool (Chip Kraft, Transportation Economics & Management Systems Inc.)
2. Animation of Switch-It Analysis Using Anylogic (Roger Baugher, TrAnalytics)
3. Boston North Terminal District: Infrastructure Demand Modeling and Improvements (Bradford Kippen, U. of Illinois U-C)

WD61: Scheduling in Passenger-oriented Railway Networks

Chair: **Nikola Besinovic**, Delft University of Technology

14:45 –
16:15

1. Functional Relationship Between Primary and Secondary Delays on Rail Lines (Steven Harrod, Technical U. of Denmark)
2. Passenger Train Service Network Design Based on a State-space-time Network (Lingyun Meng, Beijing Jiaotong University)
3. Towards Operationally Feasible and Robust Railway Timetables (Nikola Besinovic, Delft University of Technology)

INFORMS 2016 ANNUAL MEETING

NASHVILLE, TN



➤ 2016 RAS Problem Solving Competition

Chair: Francesco Corman, Delft University of Technology; f.corman@tudelft.nl

Problem Owner: Lingyun Meng, Beijing Jiaotong University; lymeng@bjtu.edu.cn

The 2016 Problem

Participants were asked to address the real world problem of scheduling train movements (production) together with maintenance operations that keep the network usable, for a complex railway network. The main challenges of the problem come from complicated infrastructure capacity regulations, and the heavy interactions between train timetabling and maintenance task scheduling.

Train timetabling is a classical problem in railway operations management. A train timetable specifies a physical network route and detailed arrival time and departure time stamps for each train at passing stations. Train timetabling is a challenging task in a saturated railway network, especially when it consists of complex stations where there are a number of crossings and switches. Maintenance of tracks is important for ensuring tracks are in appropriate states for running trains. Conducting maintenance tasks needs a blockage of tracks which means that there is complete capacity breakdown of the tracks and no train is allowed to run on the tracks during the maintenance time duration. Moreover, maintenance tasks affect operating speed of trains also in the vicinity (time and space) of the maintenance tasks.

For many years, train timetabling and maintenance task scheduling have been studied and solved separately. The competition provides a challenge for routing and scheduling trains in a railway network with combined consideration of scheduling maintenance tasks. Participants are given relevant definitions and assumptions used in the competition, inputs such as a set of trains and maintenance tasks to be scheduled, output formats, with the goal to minimize total travel time of all involved trains, subject to a number of operational constraints.

The total cash award for this year's competition is **\$3,750: First Place: \$2000; Second Place: \$1,000 , Third Place: \$750**. Visit the competition web site for additional details: <http://www.informs.org/Community/RAS/Problem-Solving-Competition>

The Response

We would like to thank all of the participating teams for their hard work. We had a total of 43 teams registered with a truly worldwide participation (with members from China, France, India, Iran, the Netherlands, Taiwan, Germany, Slovakia, Mexico, UK, and the United States), 12 of which submitted reports. Special thanks go to the all RAS board and especially the problem owner (Lingyun Meng), and the judges for proposing and keeping the level of the challenge interesting and feasible.

Three finalist teams will make their presentations at the INFORMS Annual Meeting during the RAS Problem Solving Competition Session on Sunday, November 9, 16:30 – 18:00 in the Omni Cumberland 3. Their team reports will be made available on our website (www.informs.org/Community/RAS/) soon after. We invite you to come and support these bright minds.

Finalists (in alphabetical order)

Team 2.7.2: François Galea, Sergiu Carpov, Loïc Cudennec, CEA, France

Team NCKU: I-Lin Wang, Fu-Yuan Cheng, Sih-Han Fang, National Cheng Kung University, Taiwan

Team Railsmart: Bisheng He, Yadong Liu, Yongxiang Zhang, Southwest Jiaotong University, China

Recognition

We thank the sponsors and the following organizing committee members for their efforts:

Francesco Corman (Chairman, Delft University of Technology, the Netherlands)

Lingyun Meng (Problem owner, Beijing Jiaotong University, China)

Steven Harrod (Technical University of Denmark, Denmark)

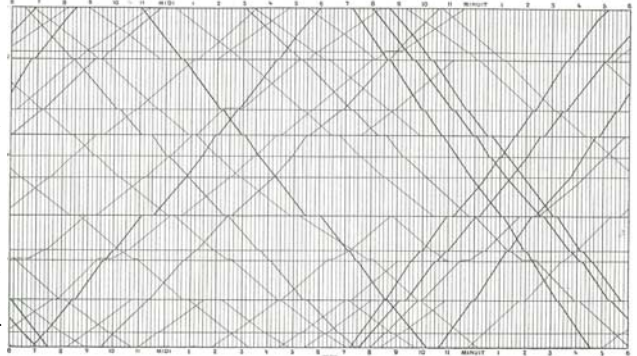
April Kuo (BNSF, USA)

Bo Zou (University of Illinois at Chicago, USA)

Fan Peng (Amtrak, USA)

Xuesong Zhou (Arizona State University, USA)

Tyler Dick (RailTEC, University of Illinois at Urbana-Champaign, USA)



2016 RAS Student Paper Awards

Chair: Steven Harrod, Technical University Denmark, stehar@dtu.dk

Rail Applications Section (RAS), a section of the Institute for Operations Research and Management Science (INFORMS), sponsored a student research paper contest on analytics and decision making in railway applications, with a total cash award of \$1,750:

First Place: \$1,000, Second Place: \$500, Third Place: \$250.

To qualify, the paper must have been written by a student or students enrolled in an academic institution during the 2015-2016 academic year. The paper must advance the application or theory of OR/MS for improvement of freight or passenger railway transportation, and it must represent original research that has not been published elsewhere by the time it is submitted. More details on the eligibility criteria, the application procedure and deadlines are available at RAS's website: <https://www.informs.org/Community/RAS/Student-Paper-Award>.

Ten students from around the world with a wide variety of topics registered for the competition. The quality of the submitted papers was in general very outstanding. Authors of the First, Second and Third Place award winning papers will present their papers at the Student Paper Award Session of the INFORMS Annual Meeting in Nashville, TN. We encourage all RAS members to attend this session and motivate our young researchers to continue to make great strides in building new models for railroad planning, scheduling and analytical problems. We provide below the abstracts of these papers. Extended abstracts of the awarded papers are available on the RAS website.

I had the honor of leading an elite paper reviewing committee made up of twelve members from different academic and industry backgrounds. In order to avoid any conflict of interest, members of the committee with any type or affinity with any of the authors or co-authors did not review the corresponding paper(s). The First Place paper will be considered for publication in Networks. The paper needs to go through the journal's normal refereeing procedure; however, the paper will receive an expedited refereeing and publication .



Rolling Stock Rescheduling in Passenger Railway Using Dead-Heading Trips and Adjusted Passenger Demand

by **Joris Wagenaar, Erasmus University, Netherlands**

Coauthor: Leo Kroon

Abstract: We propose a MILP that includes the possibility of using dead-heading trips during, and after, a disruption in the Rolling Stock Rescheduling Problem (RSRP). Furthermore, passenger flows are included to handle the adjusted passenger demand in the formulation to solve the RSRP. Results show that dead-heading trips are useful to reduce the number of cancelled trips and that adjusted passenger demand has a large influence on the rescheduled circulation.



A Polynomial Function of Primary Delays and Cumulative Delays on Railway Lines

by **Fabrizio Cerreto, Technical University of Denmark**

Coauthors: Otto Anker Nielsen and Steven Harrod

Abstract: In this paper we model the total delay on a railway line as a polynomial function of the primary delay given to a train. We define a delay propagation model to derive the individual delay of a generic train at a station. The total delay results from the summation of the individual delays and is a polynomial function of the primary delay. The model allows to compute the total delay with limited use of micro-simulation.



Balancing Performance of Timetable and Expected Schedule Robustness: Improved Space-Time Path Searching

by **Chao Lu, Beijing Jiaotong University, China**

Coauthor: none

Abstract: A novel two-stage recovery-robust timetabling framework, in which the space-time network is adopted for the modeling, is proposed for constructing an optimal robust timetable with balanced efficiency and robustness. Without fixing the commonly used variables in robust timetabling in advance, the proposed framework is aimed at finding the optimal solution from a more complete feasible region. New efficient paths refining algorithm and dispatching algorithm are proposed for solving the framework.

➤ National University Rail Center: A Hub for Railway Systems Research

Tyler Dick, University of Illinois at Urbana-Champaign; ctdick@illinois.edu

Founded in 2012, the National University Rail (NURail) Center is the first US DOT University Transportation Center dedicated to the advancement of North American rail transportation. NURail is headquartered at the University of Illinois at Urbana-Champaign and includes researchers and educators who are experts and national leaders in railway systems, infrastructure and vehicles from prestigious academic institutions in the United States. The consortium of seven partner colleges and universities offers an unparalleled combination of strengths in railway transportation engineering research and education in North America.



A primary NURail mission is to conduct research that advances railway transportation. Guided by the center themes of “Shared Corridors, Shared Challenges” and “Resilient Railroads for Robust Economies”, NURail research can be categorized into three broad areas: railway infrastructure, railway vehicles and railway systems. This latter group, with a focus on railway operating efficiency, capacity, safety, finance and policy, contains numerous research topics of interest to RAS members. Railway systems research projects at NURail partner campuses include:

- Massachusetts Institute of Technology (MIT) is considering the role of high-speed rail in providing mobility in mega-regions. MIT views high-speed rail within a complex socio-technical system that links economic development, modal choice and environmental sustainability.
- Michigan Technological University is developing a hybrid simulation approach for improving railway capacity and train schedules on shared corridors. The approach uniquely combined aspects of railway capacity and simulation methodologies from the US and Europe.
- University of Illinois at Chicago researches various policy, funding and finance projects including value capture strategies for the funding of rail construction and operation, and approaches to the environmental impact assessment of railway infrastructure.
- University of Kentucky examines US commuter rail system policy and agency approaches to preserving rural rail networks.
- University of Tennessee—Knoxville studies integrated network capacity analysis and terminal capacity models for freight rail flow analysis. Tennessee is also evaluating the impact of reduced coal consumption on the rail network in the Southeastern US.
- University of Illinois at Urbana-Champaign (UIUC) examines optimal infrastructure and operating approaches to expand rail line capacity. The effect of flexible schedules and train length on system performance is also included in this research. UIUC is also engaged in research on optimizing various railway processes such as locomotive servicing, crew assignments and maintenance scheduling. Improving rail safety through optimized inspection, routing and rolling stock designs on the basis of big data is also a key component of UIUC systems research.

Collaboration between partners is an essential element, and strength, of NURail. For example, NURail systems researchers recently collaborated with industry to stage a workshop on the “Cost of Railway Congestion” at a recent Transportation Research Board Annual Meeting.

In addition to railway research, NURail is leading efforts to expand and improve railway engineering and transport education in North America. NURail faculty are developing new rail educational materials, courses and curricula; engaging and encouraging new faculty interest in teaching rail topics, and supporting and inspiring student interest on NURail campuses, and beyond. NURail educators are increasing the breadth and depth of rail educational materials for both undergraduate and graduate students, as well as increasing course availability through traditional, short-course and on-line delivery. In both research and education, NURail is a key resource in meeting future railway systems challenges.



➤ K-12 STEM Outreach: Encouraging the Next Generation of Railway OR Professionals

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The workforce development challenges facing the railway industry have been well documented. According to a 2015 Transportation Research Board report on railroad workforce development, over 25 percent of railroad employees are aged 55 or older, and roughly 11,000 railroad employees retire each year. With approximately 10 percent of railway employees in professional management and engineering positions, this rate of attrition translates into opportunities for hundreds of graduates to enter full-time engineering positions with the US railroad industry each year.

Despite the annual demand for hundreds of students educated in railways, for various historical reasons, there are relatively few degree programs in the field of railway engineering or transportation. Most new graduates entering the rail industry have general civil, transportation or industrial engineering backgrounds with limited exposure to railway topics. Students with an interest in operations research and network planning may not recognize railways as a potential career opportunity until they have already established relationships with potential employers in other transportation fields and related OR disciplines.



One way to increase student awareness of potential careers in both railway transportation and operations research is through outreach to students at the K-12 level. Railways have a special appeal to kids (of all ages) as large, fast, powerful moving objects that easily capture one's interest. Railway-themed activities can provide an ideal platform for introducing Science, Technology, Engineering and Mathematics (STEM) concepts.



For the past two summers, the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign has hosted a one-day railway-themed STEM camp for third through fifth grade students. Through hands-on activities, the students are introduced to various fundamental railway systems, infrastructure and safety concepts.

A highlight of the STEM camp is the “Wooden Railway Simulation” where a team of four or five students, complete with Chief Financial Officer and Chief Engineer, are tasked with operating a wooden single-track railway that winds around a classroom. By taking turns and operating one wooden train across the railway at a time, the students slowly earn revenue that pays for the expense of crews and fuel. The students soon realize that they can earn more revenue faster by operating more than one train at a time. However, this leads to problems when opposing trains have no place to pass each other on the single track route. On advice of the Chief Engineer, the students are forced to invest all of their hard earned profits in passing sidings that facilitate train meets.

After suggesting the students can more efficiently earn revenue by operating longer trains, additional problems are encountered when two long trains meet at a short siding. The students are encouraged to think through possible operating solutions (should one train back up the originating terminal?) before the Chief Engineer is called upon to invest more profits in extending the length of the siding. When a passenger train is introduced, the students must construct additional sidings so all of the freight trains can clear the track simultaneously.

Perhaps in the future one of these students will be a RAS member making these same railway capacity decisions on a much larger railroad!

Experiential Learning through Industry Internships

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Participation in undergraduate or graduate railway systems research can provide students with insights into the science of railway operations planning and management. However, experiential learning through a railway industry internship can also play an integral role in educating a budding railway OR professional. Interns can apply what they have learned through their coursework, gain experience with real world problems subject to actual constraints, learn directly from practitioners and observe the inner-workings of railway management.

Academicians are extremely grateful for railroads and consultants who offer internship opportunities in the railway systems and OR fields. Not only do the students gain experience, they often return to campus with ideas to further our railway research. We asked five students from the University of Illinois at Urbana-Champaign to describe their experiences as railway interns during summer 2016.

Alexander Lovett, PhD Student

Union Pacific Railroad

Omaha, Nebraska

Network Integration and Scheduling

Key projects: Identifying blocks for subdivision, classification of unplanned crew changes, and estimating deadheads from the train plan

Software tools: Microsoft Access, MySQL and VBA

Most enjoyable aspect of internship: Presenting and discussing my project with field personnel, seeing how my work was going to be implemented and hearing that people are excited to use it

Knowledge gained: Working with the people who make and execute the operations plans helped me to see how integrated the railroad is. Everyone is dependent on other departments to make the railroad a



Sean Pengelly, Senior

Lake State Railway

Saginaw, Michigan

Business Development

Key projects: multimodal and intermodal rail transport planning, railroad acquisition, property management, transload facility development

Software tools: GIS

Most enjoyable aspect of internship: Being involved in every aspect of the railroad, including business development, engineering, transportation/operations

Knowledge gained: Interacting with all departments and “wearing many hats” allowed me to see how all aspects of the railroad interact and operate



Bradford Kippen, Master’s Student

Union Pacific Railroad

Omaha, Nebraska

Network and Capital Planning

Key projects: Developing RTC simulations to evaluate benefit and cost of proposed infrastructure projects and service changes

Software tools: Rail Traffic Controller (RTC)

Most enjoyable aspect of internship: Visiting the field to see capital projects and operations on the corridor I simulated in RTC

Knowledge gained: I learned an incredible amount about how to conduct RTC analysis and how this analysis helps to make strong business decisions for capital investment.



Darkhan Mussanov, Master’s Student

SMA und Partner AG

Santa Ana, California / Zurich, Switzerland

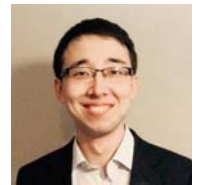
Railway System Planning

Key projects: Developing All Station OTP tool for clients and constructing Southern California infrastructure in OpenTrack

Software tools: OpenTrack simulation, Viriato, Treno, Tableau

Most enjoyable aspect of internship: Developing a mutual feedback relationship with the client and co-consultants while working towards the common goal of developing a deliverable.

Knowledge gained: Gaining insights and understanding the relationships between public organizations and host railroads on the management level



Taskin Schitoglu, Senior

CSX Transportation

Jacksonville, Florida

Network Modeling and Analytics

Key projects: comparative analysis of potential train-rerouting measures and potential use of new re-crew locations

Software tools: RTC, MySQL, Tableau, Python

Most enjoyable aspect of internship: The unique opportunity of working with a group of managers from operations research, network ops, service design and finance to discuss simulations I conducted

Knowledge gained: I further understood the ways in which data is (and isn’t used) within companies that are shifting towards being more “technology-based”





Local versus Global Optimums

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Finding a true global optimum is often the goal of solving a complex optimization problem. In evaluating different solutions, we often encounter various local optimal solutions. Frequently, these local optimum solutions arise when a variable takes on an extreme value or becomes limited by a constraint on the problem. Although not the best solution for the entire realm under consideration, these local optimums represent true optimal solutions for more extreme or highly-constrained subsets of the larger problem. The resulting solutions can take on radically different forms. In the context of railway operations research, this can lead to highly specialized operations, rolling stock and infrastructure that is fine-tuned to meet certain service and business objectives.

While attending two international conferences in 2015, along with students from the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana-Champaign, I had the opportunity to observe two different extremes of locally optimized railway operations.

Following the International Association of Railway Operations Research (IAROR) "RailTokyo" 6th International Conference on Railway Operations Modelling and Analysis in Japan during March 2015, we had a chance to make a round trip between Tokyo and Kyoto on the Tokaido Shinkansen. Operated by JR Central between Tokyo and Osaka, the Tokaido Shinkansen connects Japan's three largest metropolitan areas with a 320-mile double track dedicated passenger-only railway line. Each 16-car trainset can carry 1,323 passengers in two classes of service. The electric multiple unit trainsets weigh 788 tons and use 22,900 horsepower to reach speeds of 177 mph. Ridership is over 142 million passengers per year or 391,000 passenger per day. As one of the original and most densely traveled high-speed rail lines in the world, the Tokaido Shinkansen represents a local optimum for an extreme passenger rail operating environment.

Just a few short months later, we were able to observe the opposite extreme while attending the 11th International Heavy Haul Association (IHHA) Conference in Perth, Australia. On the IHHA conference technical tour, we journeyed to the Pilbara iron ore mining region of Western Australia to observe the Fortescue Railway. Owned by the Fortescue Metals Group (FMG) and opened in 2008, the Fortescue Railway moves iron ore 174 miles from the Cloud Break Mine to Port Hedland. To maximize efficiency, the railway has operated with 46.3-ton axle loads (compared to US mainline standard 36 ton-axle loads) since 2014. On average, 14 trains are operated between the mine and port each day. Each train consists of 240 railcars, weighs 38,800 tons fully loaded (including 32,000 tons of iron ore). Two 4,400-horsepower diesel-electric locomotives power the trains at an average speed of 35 mph. The railway operates with one-person crews, positive train control and electronically controlled pneumatic brakes. To minimize personnel requirements in the remote Pilbara region, train dispatching and rotary dump operations at the port are all remotely controlled from Perth. The Fortescue Railway represents a local optimum for an extreme freight rail operating environment.

Clearly these two railway operations are a study in contrasts, having little in common with the exception of standard track gage (4 feet 8.5 inches) and steel wheels on steel rails. However, one common thread between these two extreme operations is the importance of terminals and their effective utilization. JR Central is quick to explain how rapidly trainsets are turned at Tokyo Station so that a schedule with short headways can be supported by a minimum of station platform tracks. Similarly, FMG employs a dual-railcar rotary dump to cut unloading time at the port in half. FMG also uses compressor cars to maintain trainline brake pressure during unloading so that trains can immediately return to the mine without the need for repeated inspections and brake tests. Both FMG and JR Central go to great lengths to streamline terminal operations in order to minimize equipment cycle times, maximize asset utilization and increase efficiency. What then might these two local optimums tell us about a global optimum for the more general North American railway operating environment where freight and passenger operations co-exist? Terminal performance is likely to play an important role in optimizing these operations as well.

➤ An Open Scientific School for Railway Talents

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Beijing Jiaotong University (BJTU) grew out of the Beijing Railway Management Institute, China's first higher educational institution dedicated to fostering railway management talents, and initiated modern China's education in railway management and telecommunication.

The BJTU School of Traffic and Transportation (STT) is the birthplace of modern Chinese transportation education. STT has seven departments, with the Department of Transportation Management Engineering and Department of Urban Rail Traffic focused on education and scientific research in railway operations management. The other five departments conduct education and research in the areas of railway transportation, highway traffic and logistics.

STT has more than 180 staff members, including 45 professors and 68 associate professors, and possesses high-level teaching and research teams composed of the Yangtze River Scholars Distinguished Professor and Chair Professors. STT has more than 1500 full-time undergraduate students, about 800 full-time graduate students and 350 PhD students.

STT has participated in a number of key national research projects and has made great achievements supporting the development of Chinese transportation systems, such as the high-speed railway and heavy-haul railway. While serving the industrial development of Chinese railways, STT has published a great number of research papers in top international journals such as Transportation Research Part A-F and Transportation Science. STT accounts for 17.2% of total papers published from Mainland China.

In order to meet rapidly changing practical demands from the railway industry and provide scientific research platforms for railway talent, STT has set up a number of advanced laboratories and research centers. Meanwhile, STT also participates in the development of the State Key Laboratory of Rail Traffic control and Safety.

STT is open for international cooperation. It has close collaboration with universities from over 30 countries such as the United Kingdom, Australia, Japan, the Netherlands, the United States and Germany. STT organizes international conferences such as the International Conference of Traffic and Transportation Studies (ICTTS) and the international summer school in railway operations management (held each year since 2012). STT also invites international researchers to participate in hot-topic-oriented symposiums. Recently, STT has been involved in providing comprehensive education and research support for the development of railway systems in countries along "One belt, One road", such as Thailand.

"Blending the world, Mastery of ancient and modern", STT aims to build up world-class disciplines, educate the outstanding innovative talents in Traffic and Transportation, shape an important source of industry technological innovation, support national economic and social development, and inherit the Chinese traditional culture of harmony. STT strives to become one of worldwide leading research schools with the characteristic of traffic and transportation.





Decision Automation Opportunities in Railroads

Krishna C. Jha, Optym; Krishna.Jha@optym.com



Railroads played an important role in countries' economies for more than a hundred years. In the last few decades, they are going through an evolution process of adopting new information technologies in their planning and execution operations. This evolution has enabled railroads to monitor railcars, locomotives, and crews closely in the network. In addition to the monitoring, it has enabled quick responses to exceptions. The recent emphasis on PTC and other similar technologies has further made the real-time tracking of assets possible. These advancements in railroads technologies facilitate an adaptation of optimization-based decision automation systems.

Decision automation means computers make the majority of operational decisions while humans handle exceptions. Currently, most decisions are made by humans based on their experience and analytical capability. While a human brain can assess only a few options in the decision making, with the use of optimization techniques, computers can assess millions of options in seconds and can make decisions considering the network-wide impact and thus significantly improve operational efficiency. The following are examples for decision automation:

Train Movement Decisions: Dispatchers make decisions to stop a train on the mainline or on a siding for another train to either overtake or cross it in the opposite direction. Considering that trains follow each other closely in a single-line network, a decision to stop one train may impact a significant number of others, therefore making this one of the most complex decision problems. However, recent research work has made it possible to solve this real-life problem successfully. Software solutions like RailMAX by Optym and Movement Planner by GE are on the path to provide these decision automation capabilities.

Yard Movement Decisions: For a Class I railroad in Northern America; a railcar spends as much as 80% of its trip time in yards. Therefore, a system for optimizing railcar movements within yards has a high potential to improve yards' efficiency. The system should determine the placement and movement of railcars in a yard while considering the inbound and outbound traffic demand. The potential benefits include reduction of railcars dwell time and freeing up space to process more. The system will allow yardmasters to focus on exceptions and high-value added items. The recent proof-of-concept studies by Optym are showing significant benefits in yard operations.

Locomotive Assignment Decisions: A railroad spends billions of dollars in procuring and operating locomotives every year. A decision automation system that optimally assigns locomotives to trains considering supplies and demands can significantly reduce the locomotive cost. The potential benefits of such systems include reduction of locomotives with past maintenance due date and therefore, improvements in on-time originations and reduction of railcars dwell time.

Although exciting, there are still challenges in putting such systems in use. Some challenges include the timely availability of correct data, modeling of all business rules, trade-offs between conflicting objectives, and handling exceptions in real-time. Also, these optimization problems are also highly complex in nature. However, these challenges can be overcome using sophisticated data processing and computing techniques. For example, the meet-and-pass planning algorithms in our RailMAX system create a seven-day train movement plan in around 20 seconds for a mining company. In this system, we have also been able to overcome all data challenges using data fixing algorithms.





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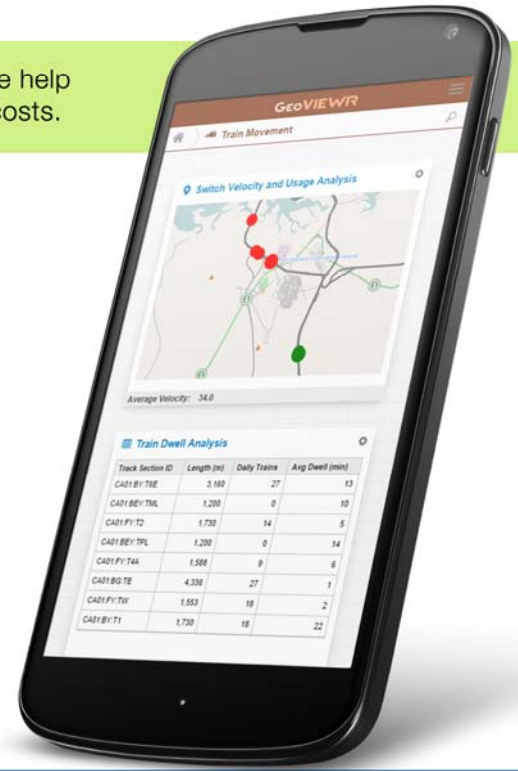
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RAS Business Meeting and Dinner at INFORMS

The RAS business meeting will be held on Sunday, November 13, from 6:15 to 7:15 pm at the Omni Room Cumberland 3. The RAS Dinner will follow at 7:30 pm at Merchants Restaurant, located at 401 Broadway in Nashville (www.merchantsrestaurant.com). The dinner is free for all RAS members and their spouses. Space is limited, so watch for a separate announcement to reserve your seats. Thanks go out to our sponsors — BNSF Railway, CSX Transportation, GE Transportation, Norfolk Southern Corporation, Oliver Wyman and Optym — for their continued support of these events and of the Rail Application Section of INFORMS. We would like to invite all RAS members for the dinner on Sunday (November 13) at the INFORMS Annual Meeting.